Step-by-Step Guide for Reproducible EEG–Quantum Nonlocal Correlation Experiments

【Required Equipment and Setup】

- Computer (Windows or Mac) — must support graphical user interface (GUI) operations and allow the installation of Anaconda.
- EEG Device: muse S or muse 2.
- Smartphone.(iOS or Android)
- Dropbox Account.
- Dropbox Mobile Application installed on the smartphone.
- Mind Monitor Application installed on the smartphone.
  For iOS:
  https://apps.apple.com/jp/app/mind-monitor/id988527143
  For Android:
  https://play.google.com/store/apps/details?id=com.sonicPenguins.museMonitor&hl=ja&pli=1
- Source Code for the Experiment:
  Please download the following code from GitHub to your computer.
  https://github.com/satorumezamel/SIEP/archive/refs/heads/main.zip

【Environment Setup Procedure】

< Environments to Be Configured >

Three environments need to be set up for this experiment:

1️⃣ Environment for EEG Measurement Using the EEG Device and Smartphone
➡ This environment enables the measurement of brainwaves and the transfer of EEG data to the smartphone, which is then sent to the computer.

2️⃣ Environment for Using Jupyter Notebook on AWS
➡ This environment connects to the quantum computer on AWS and executes quantum computations.

3️⃣ Environment for Using Jupyter Notebook on the Local PC
➡ This environment is used to perform correlation analysis between the EEG data and the quantum execution results.

< ① Installing Anaconda on the Computer >

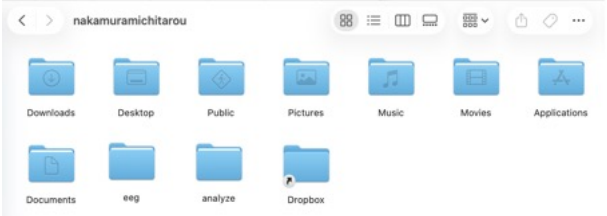
By installing Anaconda, both Python and the necessary statistical analysis packages will be installed.
Official website:https://www.anaconda.com/download/success

< ② Creating New Folders on the Computer >

Create two folders under your user directory.
The folder names can be chosen freely.

Example:

- eeg — Folder for storing CSV files containing EEG measurement results.
- analyze — Folder for storing source code used to analyze both EEG data and quantum execution results.



< ③ Creating an AWS Account >

Access the following website to create an AWS account:

https://aws.amazon.com/

Enter the required information to complete the account registration.
At this stage, please create a paid account and register a valid credit card for billing purposes.

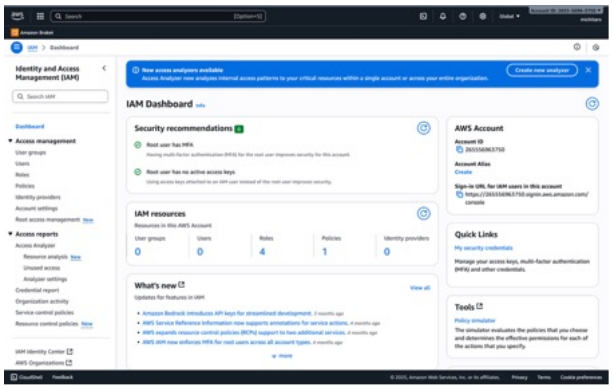
After logging in to AWS, select “United States (N. Virginia)” as the region from the menu in the upper-right corner of the screen.
This region should be selected because the quantum computers are hosted there.

< ④ Configuring a Role in AWS >

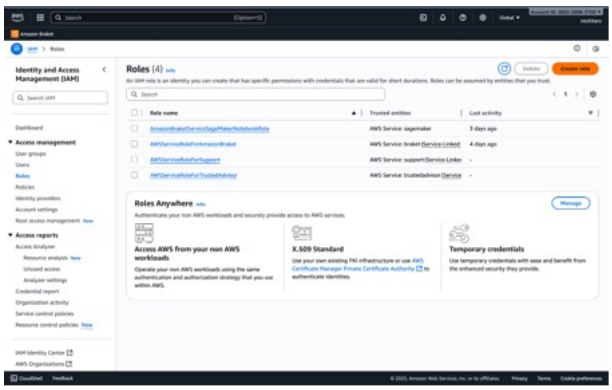
Create a service role for Amazon Braket named AWSServiceRoleForAmazonBraket.

Procedure:

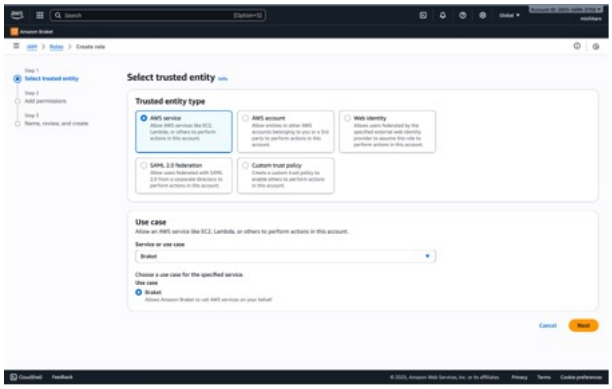
From the IAM menu, navigate to Access Management → Roles on the left-hand panel.



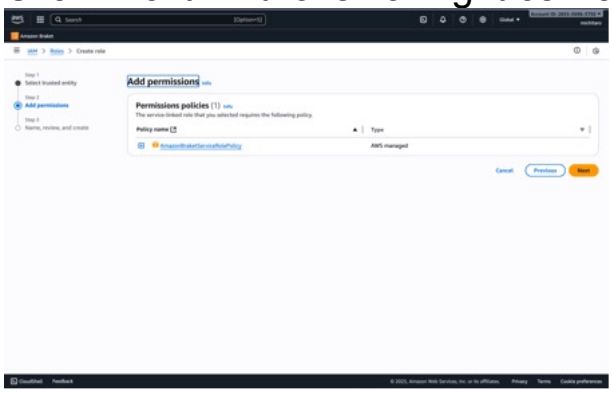
Click “Create role” in the upper-right corner of the screen.



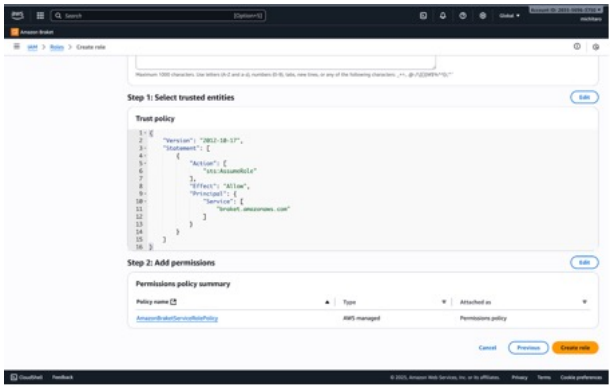
Trusted entity type:AWS service
Use case:Braket



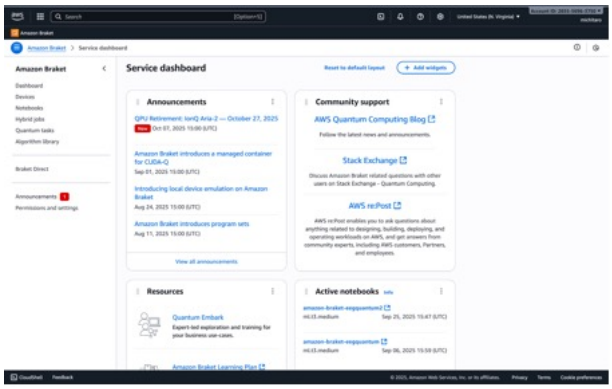
Click “Next” in the lower-right corner of the screen.



Scroll to the bottom of the page and click “Create role” to complete the role creation.

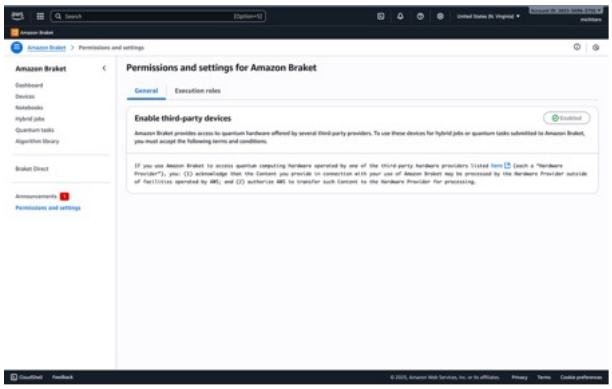


< ⑤ Agreeing to the Amazon Braket Terms of Use >



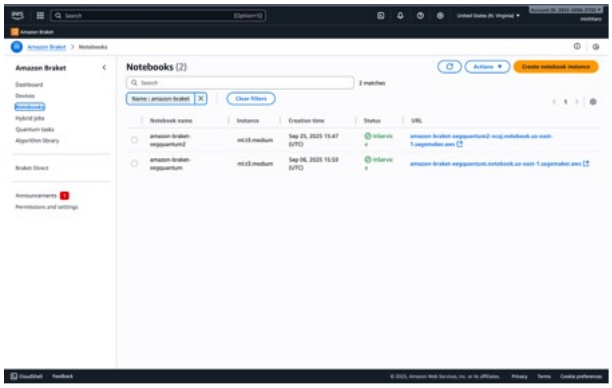
In the Amazon Braket console:

1. From the left-hand menu, navigate to permissions and settings.
2. Enable the option “Enable third-party devices.”

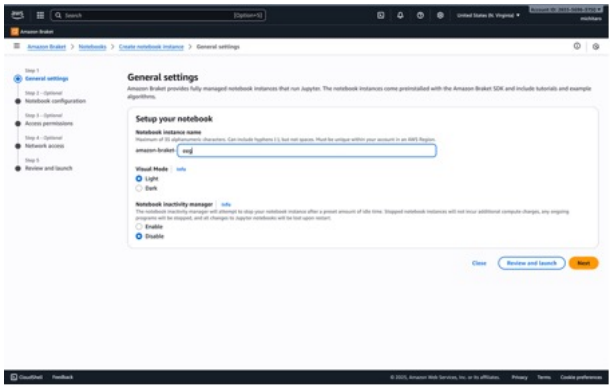


< ⑥ Creating a Notebook and Configuring S3 on AWS >

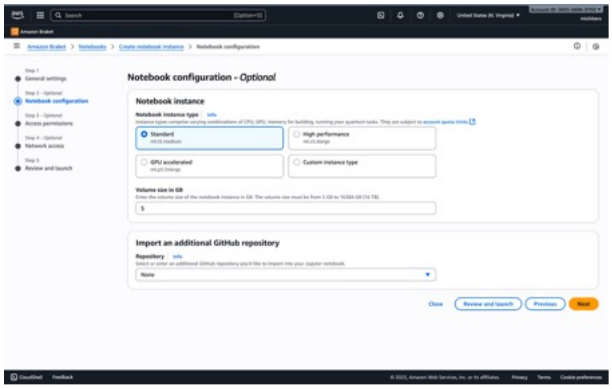
Amazon Braket → Notebooks
Click “Create notebook instance”



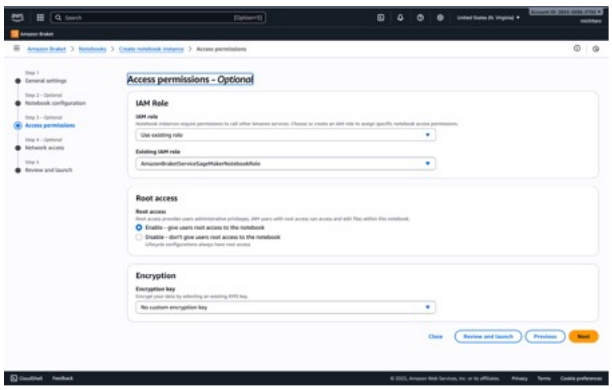
Enter any name of your choice for Notebook instance name.
Click “Next”



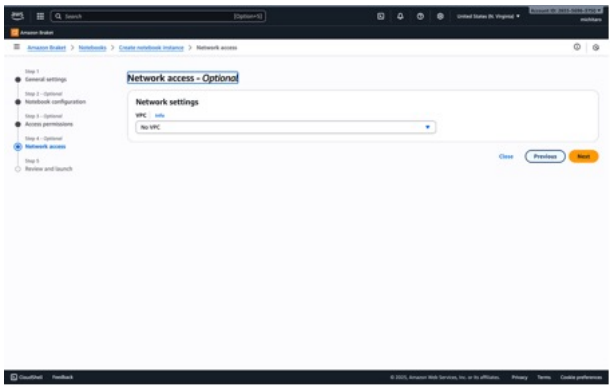
No configuration changes are required; however, you may modify the settings if necessary.
Click “Next”



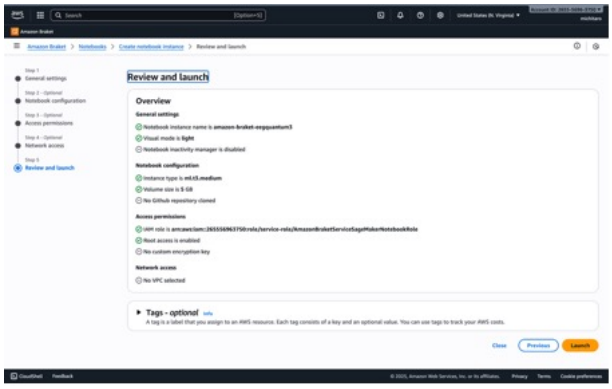
No configuration changes are required; however, you may modify the settings if necessary.
Click “Next”



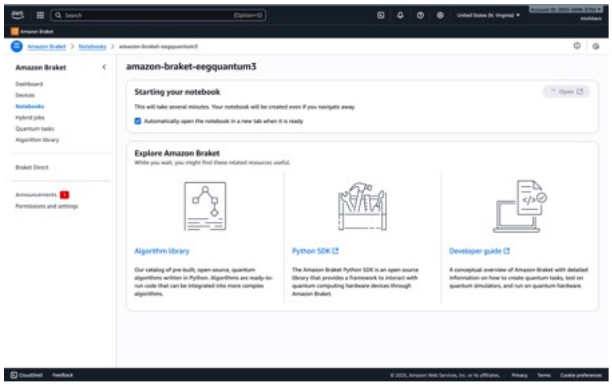
No configuration changes are required; however, you may modify the settings if necessary.
Click “Next”



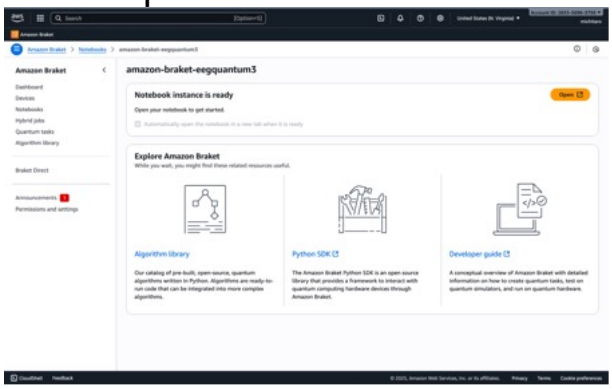
No configuration changes are required; however, you may modify the settings if necessary.
Click “Launch”



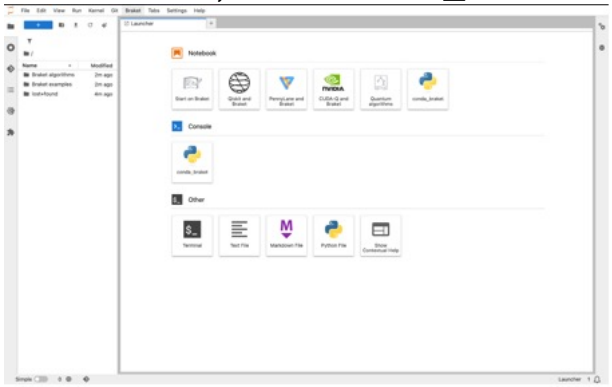
Wait a few minutes for the notebook to launch.



Click “Open”

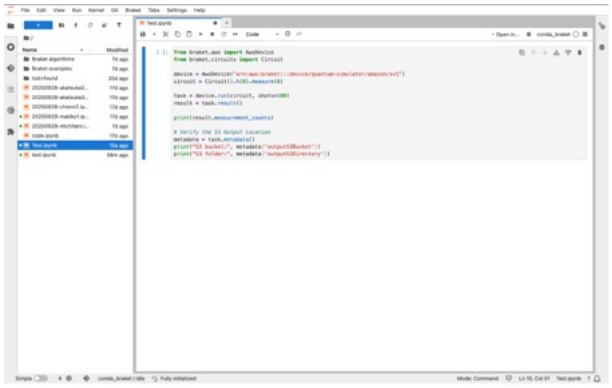


Click the blue “+” button in the upper-left corner of the screen.
In Notebook, click “conda_braket”



From the left-hand menu, rename the code file (e.g., “test.ipynb”).
For actual experiments, it is recommended to include the participant’s name in the file name so that the quantum execution results can be easily identified by subject.

Copy and paste the code from “1. Verify the S3 output location” located in the “Quantum Execution Code on AWS” folder, which was downloaded from GitHub in advance.
Then, select the code cell and press Shift + Enter to execute it.



The execution result will appear within a few seconds.
Make a note of the S3 bucket name displayed in the output.

Edit the source code in “2. 100-shot quantum execution.txt”, located in the “Quantum Execution Code on AWS” folder downloaded from GitHub. Update the S3 storage destination in the code so that it points to your own S3 bucket on AWS.

Near the bottom of the code, locate the following line and replace the first value in the parentheses with the S3 bucket name you identified earlier:
s3_folder = ("amazon-braket-us-east-1-265556963750", "tasks")

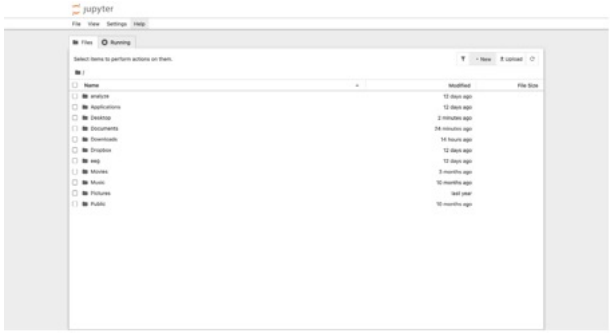
Note:
If the modified “2. 100-shot quantum execution.txt” file runs successfully and returns a result, it indicates that the connection to the quantum computer was successfully established and that the 100-shot quantum execution was completed.

< ⑦ Setting Up the Analysis Environment on the Computer >

For Mac, open the Terminal.
For Windows, open the Anaconda Prompt.
(Ensure that Anaconda has been installed.)

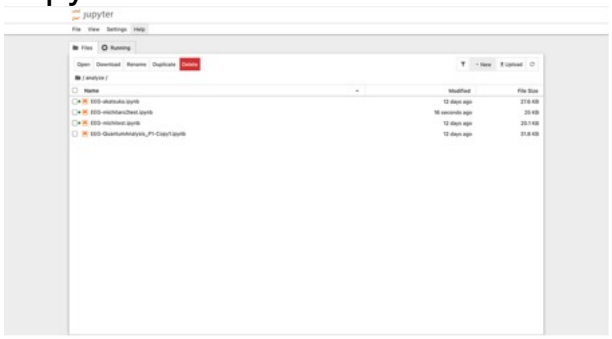
In the command line, type the following command and press Enter:jupyter notebook

Confirm that Jupyter Notebook has launched successfully in your web browser.



Upload “EEG-QuantumAnalysis_P.ipynb”, located in the “Local Analysis Code” folder that was downloaded from GitHub, to the “analyze” folder you created earlier.

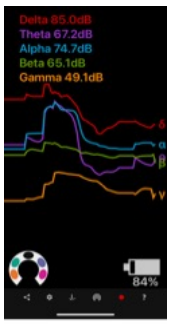
You can upload the file by clicking “Upload” in the upper-right corner of the Jupyter Notebook interface.



< ⑧ Saving EEG Measurement Results to Dropbox >

Put on the EEG headset and turn on the power.
Then, open the Mind Monitor app on your smartphone and confirm that the EEG signals are being recorded properly.

Note:
When the EEG device is connected correctly, the screen will appear as shown below.

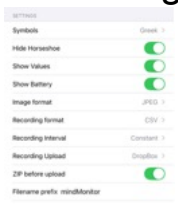


Press the gear icon in the bottom menu, then open Settings and configure the options as follows.

Recording format：CSV

Recording Interval：Constant

Recording Upload：DropBox



From the bottom menu, press the red record button (solid red dot).
If the Dropbox app has been installed, the screen will automatically redirect to it.
A folder will be created automatically, and the subsequent EEG measurement results will be uploaded as CSV files under the following path:

Apps → Mind Monitor

【Start of the Experiment】

< EEG Measurement >

Wear the EEG headset so that it sits deep enough for the sensors to rest above both ears.
Once the EEG device is stable, press the record button to begin recording.

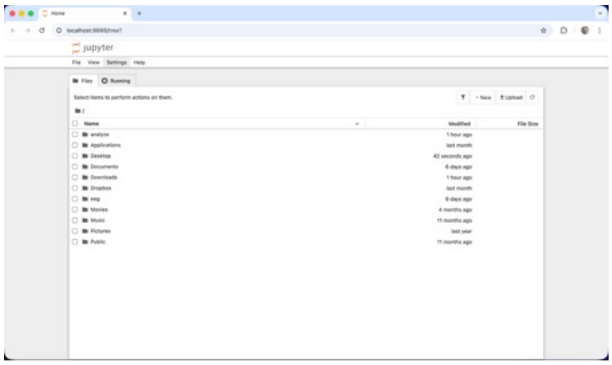
Note: Confirm that the EEG waveform is being displayed properly and that no warning icon appears in the lower-left corner of the screen.

< Launching the Analysis Environment >

For Mac, open the Terminal.
For Windows, open the Anaconda Prompt.
(Ensure that Anaconda has been installed.)

In the command line, type the following command and press Enter:jupyter notebook
If Jupyter Notebook is already running, you may skip this step.

Confirm that Jupyter Notebook has successfully launched in your web browser.
The analysis environment can be verified by checking that the URL begins with “localhost:8888.”

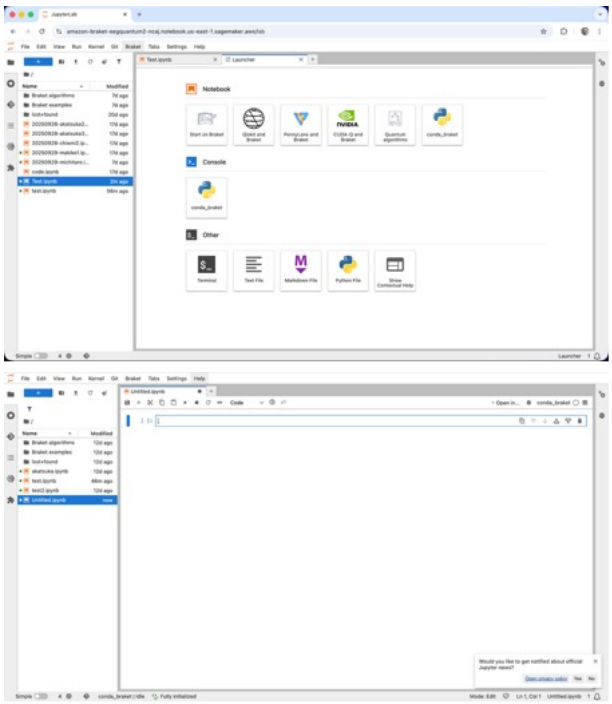


< Quantum Execution >

Log in to your AWS account, then navigate to Amazon Braket → Notebooks, and click the URL to launch Jupyter Notebook.

Since Jupyter Notebook will be running both locally on your computer and on AWS, it may be confusing to distinguish between them.
However, note that the quantum execution environment on AWS can be identified by its URL, which begins with “amazon-braket.”

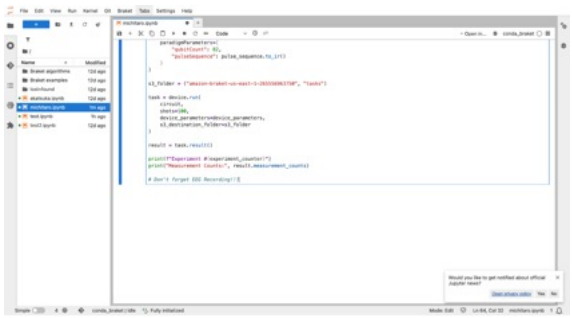
Click the blue “+” button in the upper-left corner of the screen.
In Notebook, click “conda_braket”



At this point, rename the file from “Untitled.ipynb” to something like “john.ipynb”, including the participant’s name in the filename.
This will make it easier to identify whose experimental data the file corresponds to later.

Copy and paste the contents of “2. 100-shot quantum execution.txt”—ensuring that the S3 storage destination has been correctly updated to your own AWS configuration—into the notebook, and execute the code by pressing Shift + Enter.

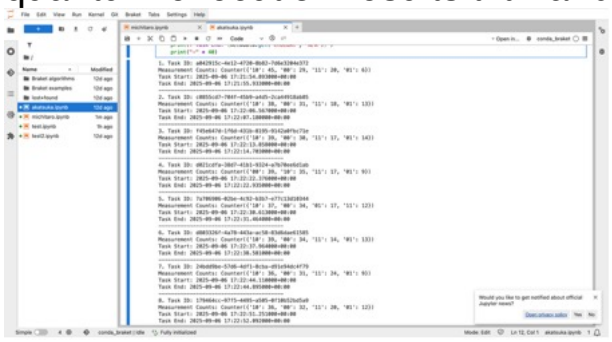
Note:
At this stage, make sure that the EEG headset is properly measuring brainwave activity.



Perform the quantum execution 30 times.
(For testing purposes, performing it 10 times is also acceptable.)

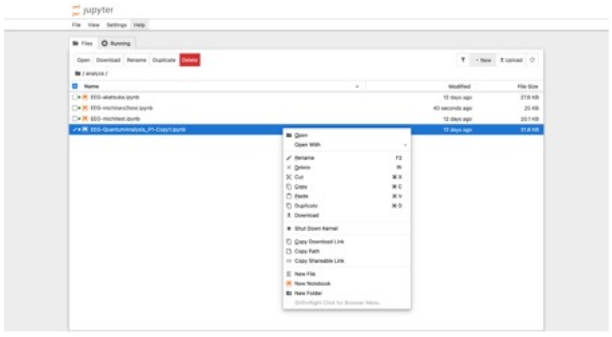
After completing the required number of quantum executions, copy and paste the contents of “3. Aggregation code for quantum execution results.txt.”
In the code, update the value of maxResults to match the number of quantum executions you performed.
Normally, this value should be set to 30, but if you performed only 10 executions for testing, set it to 10 instead.

Copy the execution results obtained from running “3. Aggregation code for quantum execution results.txt.” and save them for later use.

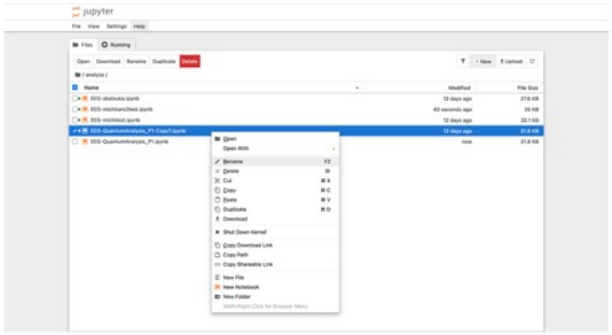


< Pasting the Quantum Execution Results into the Analysis Code >

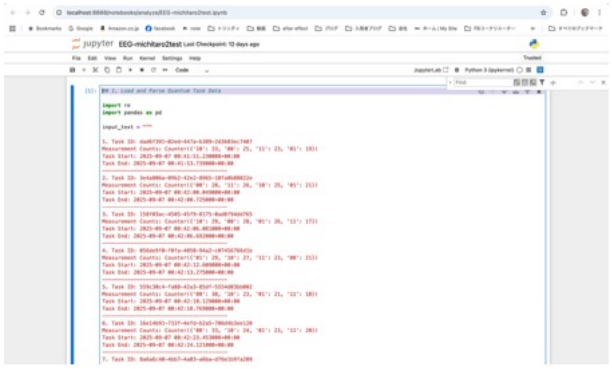
Open Jupyter Notebook in your local analysis environment (the one with a URL beginning with “localhost”).
Then, duplicate the file “EEG-QuantumAnalysis_P.ipynb.”



Rename the duplicated file to include the participant’s name.



Open the renamed file, and in the source code section that begins with
“## 1. Load and Parse Quantum Task Data,”
paste the quantum execution results into the variable input_text.



Obtaining and Preparing EEG Measurement Data for Analysis

Stop the EEG recording and save the data to Dropbox.
Then, retrieve the EEG measurement CSV file from Dropbox and place it in the “eeg” folder on your computer.

It is recommended to rename the file to include the participant’s name for clarity, for example:
“mindMonitor_2025-10-09–09-40-47_John.csv”

Open Jupyter Notebook in your local analysis environment, and in the source code section that begins with
“## 1. Load and Parse Quantum Task Data,”
update the value of eeg_file_path as shown below:

eeg_file_path = '/Users/Username/eeg/
mindMonitor_mindMonitor_2025-10-09–09-40-47_John.csv

< Executing the Correlation Analysis >

Open Jupyter Notebook in your local analysis environment (the one with a URL beginning with “localhost”),
and open the file that you renamed with the participant’s name.
Execute the four source code sections sequentially.

The purpose of each code section is as follows:

1. Load and Parse Quantum Task Data
➡ Analyzes the quantum execution results.

2. Extract and Preprocess EEG Features
➡ Analyzes the EEG data.

3. Correlate EEG Features with Quantum States
➡ Combines the results of sections 1 and 2 to perform a correlation analysis.

4. Multiple Comparison Correction (FDR)
➡ Applies an FDR correction to refine and tighten the correlation analysis, since the results from step 3 may still include less strict correlations.

Execute the code four times in total (press Shift + Enter for each section).
Make sure that each execution has completed before proceeding to the next one.

Confirm that the final correlation results appear as shown below.

	Quantum_State	EEG_Feature	Pearson_r	Pearson_p_adj	Spearman_r	Spearman_p_adj	Kendall_r	Kendall_p_adj
15	10	Delta_mean	0.603195	0.004426	0.585030	0.006776	0.439484	0.009201
16	10	Delta_peak	0.506298	0.016622	0.478567	0.026784	0.362494	0.023845
18	10	Theta_mean	0.514906	0.016622	0.399323	0.050647	0.266257	0.074017
19	10	Theta_peak	0.628528	0.004426	0.598398	0.006776	0.514058	0.002955
20	10	Theta_stability	0.422321	0.042156	0.333860	0.095543	0.253425	0.078769
46	00	Delta_peak	-0.351869	0.077931	-0.437663	0.040557	-0.302447	0.053721
49	00	Theta_peak	-0.487094	0.018579	-0.519042	0.017565	-0.362865	0.023845

【End of the Experiment】

When you are ready to end the experiment, perform the following steps:

1. Stop the EEG device and close the Mind Monitor app.
2. Log out of your AWS account.
3. Shut down the Jupyter Notebook used for analysis.
    - For Mac: Open the Terminal.
    - For Windows: Open the Anaconda Prompt.

In the command line, press Ctrl + C once.
When prompted with the message:Shutdown this notebook server (y/[n])? type y and press Enter to confirm.